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The “More Health, Less Diabetes” Randomized Controlled Trial: A Digital and In-Person Educational and Exercise Program for Type 2 Diabetes Prevention Study Protocol

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Study protocol

Keywords: Glycemic Control, Intermediate Hyperglycemia, Diabetes Risk, Diabetes Mellitus, Online training, Lifestyle intervention, Healthy lifestyle, community-based.

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Title {1a}

The “More Health, Less Diabetes” Randomized Controlled Trial: A Digital and In-Person Educational and Exercise Program for Type 2 Diabetes Prevention Study Protocol

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Abstract

Background: Type 2 diabetes mellitus (T2DM) is a major global health issue, with prevalence and healthcare-related costs rising every year. Lifestyle-related factors such as physical inactivity and unhealthy diets play a central role in disease progression. Exercise has consistently been shown to improve glycemic control at the individual level and, in large-scale prevention trials, to reduce the incidence of T2DM among high-risk populations; however, heterogeneity in intervention design and delivery limits comparability across studies. Online interventions are scalable and inexpensive, but may have limited effectiveness in sustaining health outcomes over time.. Our aim is to assess the effectiveness and cost-effectiveness of a 6-month in-person versus online lifestyle intervention in individuals at high risk of developing T2DM within 10 years.

Methods: A randomized controlled trial (RCT) will be conducted to evaluate the effectiveness and cost-effectiveness of a 6-month lifestyle intervention delivered in-person or online. For this RCT, adults at high risk of developing T2DM, as determined by the FINDRISC score, will be recruited from Portuguese primary health care units. Participants will be randomly assigned to one of three groups: an in-person intervention group (IPIG), an online intervention group (OIG), or a control group. The IPIG will participate in a 6-month program consisting of three exercise sessions per week and seven educational sessions throughout the 6-month intervention. At the same time, the OIG will follow the same online program. The control group will attend a single orientation session. During the subsequent 6-month follow-up, all participants will have the option to attend in-person exercise sessions. The primary outcome will be postprandial glucose, assessed by blood analysis following a 2-hour 75g oral glucose tolerance test. The secondary outcomes will include variables related to body composition, cardiorespiratory fitness, handgrip strength, 24-h movement accelerometry, diet, and cost-effectiveness. Primary and secondary outcomes will be measured at baseline, 6 months of intervention, and 12 months of follow-up.

Discussion: Lifestyle programs are effective and cost-effective for people at risk of T2DM, but the optimal intervention type, design, and delivery remain unclear. This trial will serve as a proof-of-concept, implementing an evidence-based lifestyle intervention program tailored to individuals at risk of T2DM and evaluating the comparative effectiveness and cost-effectiveness of in-person versus online lifestyle interventions. The findings will inform future large-scale strategies for T2DM prevention.

Trial registration: This study was retrospectively registered (NCT07079722), and the details are at: https://clinicaltrials.gov/study/NCT07079722 Registered on July 23, 2025**.

Keywords

Glycemic Control; Intermediate Hyperglycemia; Diabetes Risk; Diabetes Mellitus; Online training; Lifestyle intervention; Healthy lifestyle; community-based.

Structured summary {1b}

Table 1-Structured Summary

Item	Description
Primary Registry and Trial Identifying Number {4}	"More Health Less Diabetes", https://clinicaltrials.gov/study/NCT07079722 registered on clinicaltrials.gov, with registration ID: NCT07079722, Registered on July 23, 2025**
Secondary Identifying Numbers	There are no secondary identifiers
Source(s) of Monetary or Material Support	Portuguese Directorate-General of Health
Primary Sponsor and contact information {3b}	Portuguese Directorate-General of Health, diabetes@dgs.min-saude.pt
Role of sponsor and funder {3c}	The three authors from PND, which is part of the Portuguese Directorate-General of Health, played a role in designing and implementing the program's educational component. The funder has no role in the program's exercise component.
Contact for Public Queries	diabetes@dgs.min-saude.pt
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Public Title	*More Health, Less Diabetes*
Scientific title	The "More Health, Less Diabetes" Randomized Controlled Trial: A Digital and In-Person Educational and Exercise Program for Type 2 Diabetes Prevention
Countries of Recruitment	Portugal
Health Condition(s) or Problem(s) Studied	Intermediate hyperglycemia
Intervention(s)	Lifestyle Intervention
Key Inclusion and Exclusion Criteria	Inclusion criteria: 1) FINDRISC score indicating High or Very High risk; 2) No diagnostic criteria for diabetes; 3) Committed to adopt lifestyle changes for diabetes prevention; 4) Proficiency in using digital devices and internet access; 5) Availability to attend sessions as scheduled. Exclusion criteria: 1) History of

	cardiovascular incidents; 2) Reported pregnancy; 3) Motor limitations that limit the practice of physical exercise; 4) inability to provide informed consent; 5) taking any weight control drugs (e.g., GLP-1 analogs);
Study Type	Randomized Controlled Trial
Date of First Enrollment (planned)	01/09/2025
Sample Size	120
Primary outcome(s)	Post-prandial glucose after an Oral glucose tolerance test
Key Secondary outcome(s)	Body composition, Maximal aerobic capacity, Glycated hemoglobin, fasting glycemia, 24-hour movement accelerometry, diet, socioeconomic status, quality of life, physical activity level, and medical resources consumption.
Ethics Review	This study protocol was approved by the Ethics Commission for Health of the Local Health Unit of Western Lisbon (approval code: 2025-15).
Individual Trial Participant Data sharing statement	No individual clinical trial participant-level data will be shared.

Protocol version {2}

20/10/2026, version 2

Introduction

Background and rationale {9a}

Diabetes is a significant public health concern affecting approximately 11.1% of the adult population (588.7 million people), with projections suggesting an increase to 852 million by 2050 (1). In some countries, the statistics are even worse. For instance, in Portugal, the most recent data, published in 2025, indicate that diabetes affects approximately 14.2% of the population aged 20-79, with an additional 28.8% of the Portuguese population having intermediate hyperglycemia (2, 3).

These alarming values impose a financial burden on the Portuguese healthcare system, with annual direct expenditures accounting for 8% of total healthcare spending (2, 3). Given this data, there is clear evidence that 70% of people with intermediate hyperglycemia tend to develop type 2 diabetes mellitus (T2DM) in a 10-year follow-up (4). Risk factors such as higher BMI and waist circumference, physical inactivity, an unhealthy diet, and poor health literacy are directly associated with the development of T2DM (5). Furthermore, from the early stages of pre-diabetes, there is strong evidence of structural and functional vascular changes, which are known to increase in the medium to long/term micro and macrovascular complications (6, 7).

From economic and public health perspectives, exercise interventions in community settings are worthwhile investments for the management and prevention of T2DM (8). The Diabetes Prevention Program (DPP) found

that 5-7% of participants in this large-scale community program who met physical activity goals reduced their likelihood of developing T2DM by 44%, independent of weight loss. (9, 10). The 15-year follow-up study of the DPP has also shown that a lifestyle intervention is superior to medication alone in preventing the development of T2DM (11). Moreover, it underscores the importance of exercise in improving health-related biomarkers in individuals with T2DM (12-16).

Despite its known benefits, evidence suggests that comparability across exercise interventions is limited by several factors, including heterogeneity in intervention type, design, and delivery (13, 17, 18). For instance, studies have explored the impact of online versus in-person delivery of lifestyle interventions (19, 20). The current body of literature on online interventions suggests that improvements in health-related outcomes may be compromised in the medium- to long-term (21-23). Thus, while online interventions have shown promise due to their scalability and lower cost, evidence suggests that their medium- to long-term effectiveness in sustaining health-related outcomes may be limited, thus highlighting the need to evaluate the same program on both delivery methods (19, 24, 25).

Explanation for the choice of comparator {9b}

This trial targets individuals at high or very high risk of developing T2DM. This trial targets individuals at high or very high risk of developing T2DM by comparing in-person and online lifestyle interventions that target the individual's daily physical activity and diet against a control group that receives only an initial orientation. The study aims to evaluate the relative effectiveness of each delivery method and determine its added value over standard care.

Objectives {10}

This paper describes the protocol of the ‘More Health, Less Diabetes’ project, a randomized controlled trial (RCT) designed to evaluate the effectiveness and cost-effectiveness of a 6-month in-person versus online lifestyle intervention (exercise plus educational sessions) in individuals at increased risk for T2DM. The primary outcome will be 2-hour postprandial glycemia, measured during an oral glucose tolerance test (OGTT) at baseline and at the 6- and 12-month follow-up. The project further aims to enhance health literacy and promote sustainable lifestyle changes, including improved dietary patterns, increased physical activity, weight management, and smoking cessation.

Methods: Patient and public involvement, and trial design

Patient and public involvement {11}

Patients were not directly involved in the design of this trial. However, the intervention follows standard guidelines that prioritize patient safety.

Trial design {12}

This trial is an RCT comprising three arms: an In-person (IPIG) educational and exercise program, an online (OIG) educational and exercise program, and a control group, allocated in a 1:1:1 ratio. This RCT will include a 6-month structured exercise and educational intervention, followed by a 6-month follow-up. Both intervention groups will undergo a combined exercise training program comprising resistance and aerobic components. The control group will not engage in structured exercise and will be invited to an initial session on physical activity and healthy habits. This study protocol was approved by the Ethics Commission for Health of the Local Health Unit of Western Lisbon (approval code: 2025-15) and is currently registered at ClinicalTrials.gov (Trial ID: NCT07079722)

	STUDY PERIOD			
	Enrolment	Allocation	Post-allocation	Follow-up
TIMEPOINT	Pre-baseline	Baseline	6-month	12-month
Enrolment				
Eligibility screen	X			
Informed Consent	X			
Allocation		X		
Groups				
In-person		●	●	●
Online		●	●	●
Control		●	●	●
Assessments				
2hr- Oral glucose Tolerance Test		X	X	X
Dual-energy X-ray absorptiometry		X	X	X

Bioelectrical impedance Analysis		X	X	X
Anthropometry		X	X	X
Maximal Cardiopulmonary Exercise Test		X	X	X
24-hour movement accelerometery		X	X	X
Sleep Quality		X	X	X
Handgrip strength		X	X	X
Questionnaires		X	X	X
Food Records		X	X	X
Cost-effectiveness analysis		X	X	X

Figure 1- SPIRIT Figure

Methods: Participants, interventions and outcomes

Trial setting {13}

Participants will be recruited for a community intervention study of individuals with prediabetes or at high or very high risk of T2DM, using risk stratification based on the FINDRISC questionnaire (26). Recruitment will be conducted through consultations at the Health Centers in the municipality of Oeiras. After initial contact, participants will receive a telephone call to confirm eligibility and explain the study and its benefits for the patient, if they decide to participate. The third contact with the participant will involve obtaining informed consent and scheduling the following assessments.

Characteristics of the people who are needed for the trial

Table 2- Population Characteristics

Characteristic	**The people we would expect to see included**
Age	≥18years
Sex	Male and Female
Gender	Man and Woman.
Race, ethnicity and ancestry	Race and ethnicity data will be collected via self-report during the baseline assessment. Participants will be asked to select the category that best describes their ethnic background.
Socioeconomic status	Socioeconomic status will be assessed on the baseline assessments.
Geographic location	Portugal, municipality of Oeiras
Other characteristics relevant to the trial	Not Applicable

Eligibility criteria for participants {14a}

Participants are included if: 1) FINDRISC score indicating High or Very High risk; 2) No diagnostic criteria for diabetes; 3) Committed to adopt lifestyle changes for diabetes prevention; 4) Proficiency in using digital devices and internet access; 5) Availability to attend sessions as scheduled; 6) ≥18 years. Exclusion criteria: 1) History of cardiovascular incidents; 2) Reported pregnancy; 3) Motor limitations that limit the practice of physical exercise; 4) Inability to provide informed consent; 5) Taking any GLP-1 analog drugs

Eligibility criteria for sites and those delivering interventions {14b}

There will be no need for site-specific eligibility criteria, as this trial is conducted exclusively in the Exercise and Health Laboratory of the Faculty of Human Kinetics, Lisbon, Portugal

Who will take informed consent? {32a}

The principal investigator will contact all potential participants to provide a clear explanation of the trial, including the number and types of assessments, the duration and nature of the intervention, and the required time commitment. This process will ensure that all questions are addressed before the baseline evaluation. During the baseline assessment, a trained evaluator (a Ph.D. candidate with an Exercise physiologist with a master's degree in Exercise and Health) will be available to clarify any remaining questions before obtaining written informed consent.

Additional consent provisions for collection and use of participant data and biological specimens {32b}

The consent form will include a statement asking participants whether they consent to the use of their data if they withdraw from the trial. Additionally, participants will be asked to authorize the research team to share relevant data with members of the university involved in the study or with regulatory authorities, as applicable.

Intervention and comparator

Intervention and comparator description {15a}

<u>Exercise Component</u>

Both intervention groups (OIG and IPIG) will participate in a combined exercise training program with strength and aerobic components, delivered in separate 45-60-minute sessions. Each week will have 3 exercise sessions following a non-linear periodization design. The training protocol alternates monthly between strength- and aerobic-dominant phases. Consequently, over the year, there are six strength-focused months and six aerobic-focused months. Each strength-focused month comprises six strength sessions, three aerobic sessions, and three combined sessions. Conversely, each aerobic month consists of six aerobic sessions, three strength sessions, and three combined sessions. This non-linear periodization design will allow for greater variability and increase long-term exercise adherence.

Aerobic training sessions will use 45-60 minutes circuit training at 60–90% of heart rate reserve with different types of methodologies: as many rounds as possible (AMRAP), every minute on the minute (EMOM), and classical circuit (time/repetition defined, rest between exercises and laps defined) using battle ropes, fitness balls, bands, and calisthenic, and more traditional methodologies, such as walking at 60-80% HRR. Intensity and energy expenditure will be recorded using heart rate monitors.

Strength training sessions will use 45-60 minutes, will be performed at 65–80% of one-repetition maximum (RM), controlling the intensity using 1 to 3 repetitions in reserve (7-9 rating of perceived exertion), 2-3 sets, with 6-8 exercises for the major muscle groups, using different methodologies, classical strength training with other variations, staggered superset, cluster sets. Each session will include push, pull, hip-dominant, knee-dominant, and core exercises. The materials to be used are elastic bands (2 different resistances), fitness balls of various weights, and calisthenics.

An additional option is combining aerobic and strength training in a single session that does not exceed typical volume/duration (maximum 60min). The exercise sessions will be divided into two parts: one involving aerobic exercises using the same methodologies described, and the other with a strength component, also employing the methods described previously.

Each exercise includes progression and regression to accommodate participants' individual needs. Every exercise session will have a 5-10-minute warm-up and cooldown. The warm-up is based on the RAMP method (27) and includes ludic components (e.g., social games). The RAMP method consists of a “raise” exercise, for example, a cardiovascular game to be engaging and increase body temperature; two exercises of “activation and mobility”, for example, whole body joint mobility; and “potentiate” with two to three exercises that will be inserted in the central part of the session, for example, one upper body, one lower body and one core exercise. The cool-down phase will last 5 minutes and will follow the ACSM guidelines for flexibility training (28).

Exercise sessions will be similar across the two intervention groups. All the participants will wear a heart rate monitor to record and control total energy expenditure, which will be used to control the sessions. Furthermore, attendance, perceived training intensity, and training satisfaction will also be recorded. The OIG participants will attend synchronous online exercise classes and will have free access to all materials needed to complete their exercise training at home.

The control group will not perform structured exercise and will be invited to an initial orientation session. At the end of the 6-month intervention, they will receive free access to the in-person exercise sessions for the following 6 months. This group will be assessed at the same time points with the same protocol. The 6-month follow-up period will use the same methodology as the 6-month intervention period.

Educational Component

The educational sessions, in person or online, were built on Self-Determination Theory principles to address the basic needs of perceived autonomy, competence, and relatedness for health behavior change (29).

OIG will access online educational sessions via a digital platform that will include seven informational videos with practical tips and short quizzes on diabetes prevention. These videos will support autonomy by allowing participants to choose the order and timing of viewing, and answer reflective questions about which strategies best fit their routines; they will support competence through progressively challenging quizzes with immediate explanatory feedback and short “try this at home” tasks (such as setting one specific weekly goal and monitoring it). They will foster relatedness by including short patient stories and prompts to discuss the content with family, peers, or the intervention group between sessions. IPIG will have seven in-person educational sessions (every 4 weeks) and a follow-up session 3 months after the last one. Across these sessions, autonomy will be targeted through collaborative agenda setting (participants help prioritize subtopics and questions), opportunities to set personal behavior-change goals, and invitations to adapt strategies to their own contexts; competence will be targeted using clear explanations, step-by-step skill practice (e.g., reading food labels, planning weekly physical activity), and regular review of progress; relatedness will be targeted through small-group discussions, peer sharing of successes and barriers, and a supportive group climate fostered by the facilitators.

Educational session and will have the following topics: (1) Diabetes, risk factors, and prevention – includes an interactive discussion where participants identify personal risk factors and identify prevention strategies and correct risk perceptions; (2) Facilitating the development of habits – includes guided exercises to design individually chosen “if–then” routines (e.g., walk after lunch on workdays), practice planning around barriers,

and share habit ideas (3) Healthy eating to prevent diabetes – includes hands-on label-reading examples and strategies to menu-planning tailored to each person's cultural and family context and feasible changes; (4) Physical activity(ies): why and how – includes brief explanations of health benefits, options to choose preferred activity types and intensities, practical demonstrations with individualized adaptations; (5) Strategies for weight control – includes exploration of personally meaningful reasons for weight management, selection of self-monitoring and problem-solving strategies that participants feel able to use; (6) Safely practicing physical activity – includes exploration of the places where the participants can do their physical activity safely, and different opportunities for it; (7) Facilitating the maintenance of habits- includes guided exercises to understand how the participants will continue the exercise sessions and heathy habits that they engage in after the 6-months.

Criteria for discontinuing or modifying allocated intervention/comparator {15b}

Following randomization, in which participants are allocated to predefined groups, reassignment to a different group is not permitted.

Strategies to improve adherence to intervention/comparator {15c}

To increase adherence to the intervention, we intend to organize monthly group meetings (up to 1 per month) for the three groups (IPIG, OIG, and control), including short Sunday walks, mini golf, volunteer beach cleanups, and other activities to foster a sense of community. Beyond those activities, the MHLD intervention is grounded in self-determination theory, and, thus, as mentioned, the three basic psychological needs, such as autonomy, competence, and relatedness, will be supported throughout the activities. For example, to nourish autonomy, participants manage their own intensity and energy expenditure with heart rate monitoring; to nourish competence, the exercises are adapted to provide optimal challenge (neither too low nor too high) according to participant level; and to nourish relatedness, there are some cooperative and competitive exercises to create the sense of group union.

Concomitant care permitted or prohibited during the trial {15d}

In accordance with the ecological approach, participants were not prohibited from any activities during the trial, except for changes in medication, such as the addition of GLP-1 analogs.

Ancillary and post-trial care {34}

We do not expect any harm from this intervention; nevertheless, to prevent potential injury and dropout, every participant will begin the program with an adaptation period, the first month of training. Moreover, every participant is insured against injury.

Outcomes {16}

Primary

The primary outcome of “More Health, Less Diabetes” will be postprandial glucose, objectively assessed by blood analysis following a 2-hour 75-g oral glucose tolerance test (OGTT).

Secondary

The secondary outcomes of this protocol will be body composition((i.e., total and regional fat mass and lean body mass, abdominal and gynoid body fat mass, and bone mineral content and density, all assessed by dual energy X-ray absorptiometry (DXA)), waist and hip circumference, body mass index, total body water, intracellular and extracellular water (estimated by bioelectrical impedance analysis (BIA)); maximal aerobic capacity, PPO, and pre-existing heart conditions assessed through a cardiopulmonary exercise test (CPET); T2DM risk, socioeconomic status, quality of life, physical activity level, and diet (all estimated by questionnaires); beyond the OGTT, HbA1c and fasting glycemia will be collected from the blood samples; 24-hour movement, including physical activity volume and intensity (total minutes at light, moderate, and vigorous intensity, total counts, and counts/minute), time spent in sedentary behavior, as well as patterns on how each of these behaviors are accumulated (i.e., bouts of time spent in sedentary behavior or physical activity), and sleep patterns, using an altigraph gt3x on non-dominant wrist (accelerometry); handgrip strength; Water and energy intake will be assessed using three-days food records; and Cost-effectiveness will be assessed using the 2h-OGTT as the primary effectiveness measure, and by calculating both direct and indirect costs, including medical consumption measured with the iMTA Medical Consumption Questionnaire (iMCQ).

Harms {17}

This trial poses minimal risk to participants; however, participants will be encouraged to report any injury, adverse event, or unexpected reaction to the protocol during the intervention period. All reported adverse events will be recorded by the research team, including their type, severity, and frequency. Moreover, all the participants will be covered by insurance.

Participant timeline {18}

The temporal organization of the baseline, the six-month intervention, and the six-month follow-up is shown in Figure 2. The participants will be divided into two cohorts; each cohort will enter and be assessed at the same time points.

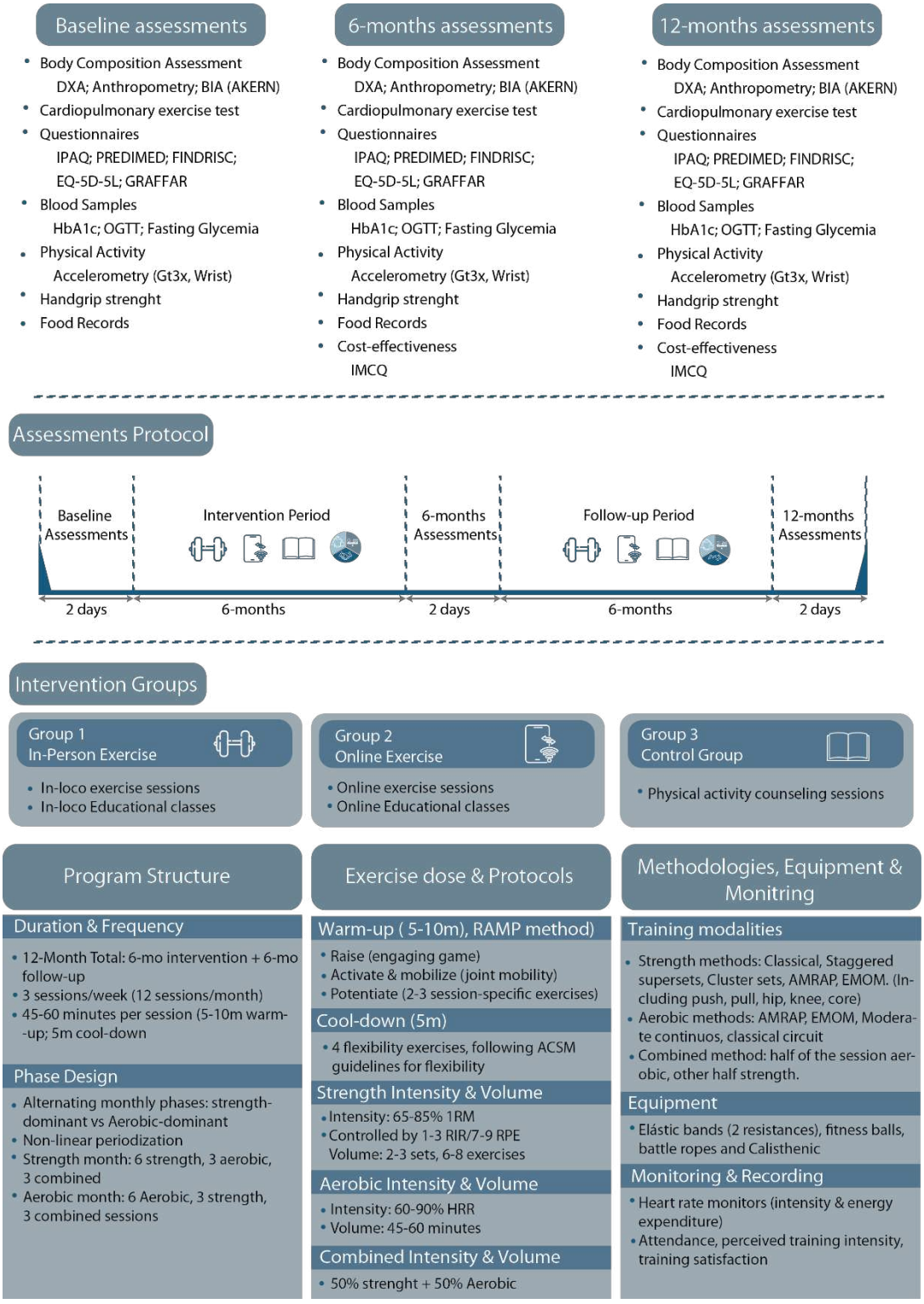


Figure 2- Participants Timeline

Abbreviations: DXA, Dual-energy X-ray absorptiometry; BIA, Bioelectrical impedance analysis; HbA1c, Glycated hemoglobin; OGTT, oral glucose tolerance test; RM, repetition maximum; RIR, repetitions in reserve; RPE, rating of perceived exertion; HRR, heart rate reserve; AMRAP, as many rounds as possible; EMOM, every minute on the minute.

Sample size {19}

Based on the sample size calculation to detect a moderate-to-large effect (Cohen's d≈0.64) of a lifestyle intervention on 2-h glucose OGTT in adults with prediabetes, as observed in the DPP (21) (a mean reduction of 1.6 mmol/L and an SD of 2.5 mmol/L in 2h OGTT), and accounting for a 15% dropout rate from our previous experience, we plan to recruit 120 participants (40 per arm in 1:1:1 ratio).

Recruitment {20}

All recruitment will be conducted at primary health care units within the municipality of Oeiras. The first contact will be through consultations conducted by health professionals at primary health care units in the municipality of Oeiras. This initial contact will propose presenting the project to participants and screening them for eligibility. The second contact will be a telephone call during which the study will be briefly explained, and the advantages for the patient, if he decides to participate, will be outlined. The second contact with the participants will involve: Explaining the study in more detail, underlining the benefits for the participant, completing a participant form with the following data: name, address, telephone contact, e-mail (if any), and availability to attend the training sessions, and scheduling the 3rd contact with the participants at FMH. The 3rd contact with the participant will involve obtaining informed consent and scheduling the following assessments.

Assignment of interventions: randomisation

Sequence generation: who will generate the sequence {21a}

Random allocation will be performed by another investigator in the Exercise and Health Laboratory, who will not be directly involved in data collection.

Sequence generation: type of randomisation {21b}

After baseline assessments, all participants will be randomly assigned to one of the three groups in a 1:1:1 ratio. This allocation will be performed using an automated tool, Stata, version 13.1 (StataCorp LLC, College Station, TX, USA) by an independent investigator who is not involved in participant recruitment, assessment, intervention delivery, or outcome evaluation.

Allocation concealment mechanism {22}

Once all baseline measurements are completed, allocation concealment will be implemented to ensure that participants remain unaware of their group assignment until the intervention begins. An independent third-party investigator will randomize the experimental sequence.

Implementation {23}

Participants will be allocated to one of the three groups, and after baseline assessments, all participants will be informed of their group assignment: control group, OIG, or IPIG.

Assignment of interventions: blinding

Who will be blinded {24a}

During the baseline assessment, participants and fieldwork staff will not know their allocation group, as randomization will be performed after baseline assessments. After baseline assessments, it will be impossible to blind staff and participants due to the nature of the intervention.

How will be blinding be achieved {24b}

Blinding will be strictly maintained during the baseline assessment phase. Since the randomization procedure is performed by an outside investigator after baseline data collection, neither participants nor evaluators will be aware of group allocation at that stage. However, due to the nature of the trial, it is impossible to maintain blinding during the intervention phase.

Procedure for unblinding if needed {24c}

Unblinding will occur after randomization is complete and before participants are informed of their group assignment. At this stage, the trial manager, data coordinator, implementation facilitators, and participants will have access to the group allocations.

Data collection and management

Plans for assessment and collection of outcomes {25a}

All body composition measures, questionnaires, handgrip strength, 24-hour movement, food records, and cost-effectiveness variables will be collected at the Faculty of Human Kinetics, University of Lisbon.

Cardiopulmonary exercise testing will be performed at the Faculty of Medicine, University of Lisbon. Blood samples will be collected at a certified laboratory, a specialized laboratory located near the Faculty of Human Kinetics. Every assessment will be repeated at each time point (baseline, six months, and twelve months).

Primary Data Collection

Blood glucose analysis will be used to assess postprandial glucose after a 2-hour 75-g oral glucose tolerance test. This exam will be conducted at a certified laboratory by certified healthcare professionals. This procedure will be repeated at each of the three points to assess changes in plasma glucose level two hours after ingestion of 75g of glucose. At each time point, blood will be collected at rest after an overnight fast of at least 8 hours, in a seated position from the antecubital vein. The laboratory team will analyze blood samples. All samples will be analyzed once and subsequently disposed of in accordance with the laboratory clinical protocol.

Secondary data collection

Anthropometric measures, such as weight, height, waist circumference, and hip circumference, will be taken with the participant wearing minimal clothing. Weight and height will be measured to the nearest 0.1cm and 0.1 kg using a digital scale with an integrated stadiometer (Seca, Hamburg, Germany). BMI will be calculated by dividing weight (Kg) by height squared (m^2). Waist and hip circumferences will be measured using a standardized tape measure to calculate the waist-to-hip ratio.

Body Composition DXA (Hologic Explorer-W, fan-beam densitometer; QDR for Windows version 12.4; Waltham, USA) will be used to determine total and regional fat-free mass and fat mass, as well as bone mineral content and density. All scans will be conducted and analyzed by the same laboratory technician, who will follow the operator's manual and apply the standard analysis protocol.

Whole-body bioelectrical impedance analysis (BIA) will be performed using AKERN equipment (Akern BIA 101/BIVA PRO), a single-frequency, phase-sensitive BIA device (SF-BIA). Participants will be instructed to lie down for 10 minutes. Before measurement, their legs will be abducted at 45° relative to the body's median line and their arms at 30° from the trunk. After cleaning the participants' skin, eight low-impedance electrodes (Biatrodes, Akern Srl, Florence, Italy) will be used to measure the raw parameters, such as resistance (R), reactance (Xc), phase angle, impedance, total body water, intracellular water, and extracellular water, placing them on the dorsal surfaces of the feet and ankles and on the wrists and hands (30). Calculations of the ECW/ICW ratio will be performed afterwards.

Food Records. Before the start of the project, participants will complete a 3-day dietary record to assess energy and water intake (31). This procedure will be repeated at 6-month and 12-month time points. Participants will be instructed to complete the food record as accurately as possible, with explanations of portion sizes, aspects of food preparation, and other relevant information. Food records will be analyzed using Food Processor Plus® (version 10.12.0.0, ESHA Research, USA). To identify under- and overreporting, the ratio of energy intake to resting energy expenditure (REE) will be used (32). The REE will be estimated using the Schoefield equations (33). The cut-offs used will be 1.1 for under-reporting (34) and 4.0 for over-reporting (35), with values outside this range excluded.

Cardiopulmonary exercise testing (CPET): A maximal cardiopulmonary exercise test (CPET) will be performed on a cycle ergometer under the supervision of a cardiologist. Using a 12-lead electrocardiogram and a gas analyzer (CARDIOVIT CS-200 Office ErgoSpiro), the test will assess cardiorespiratory fitness and monitor for any cardiovascular complications. A ramp protocol will be applied, starting at 20 watts (W), with regular increases of 7 W, 10W, 15W, 20W, or 25W, while maintaining a constant pedal frequency of 60-70 rotations/min. The protocol will be defined based on medical history, perceived physical fitness, and experience with physical exercise to achieve a test conclusion in 8-12 minutes. Before the protocol, a 2-minute warm-up/familiarization period is conducted to verify proper bike adjustment. At the end of the protocol, a 3-5-minute recovery period will be included. VO_2peak will be defined as the highest 20-second average of oxygen consumption (ml/kg/min) achieved during the final minute of the exercise test, provided that participants reached volitional fatigue and met at least one of the following objective criteria: (1) a respiratory exchange ratio ≥ 1.10; (2) attainment of the age-predicted maximal heart rate; or (3) a plateau in oxygen uptake despite an increased workload.

Questionnaires Different questionnaires will be applied to evaluate socio-economic status, using the GRAFFAR questionnaire (36), the Daily physical activity with reduced IPAQ (37), the PREDIMED questionnaire (38) to understand if participants are adopting the Mediterranean diet, the EQ-5D-5L (39) to assess participants' quality of life, and the FINDRISC (26) to evaluate participants' risk of developing T2DM in 10 years.

24-hour movement and sleep activity, as well as daily physical activity, will be assessed using ActiGraph GT3X accelerometers (ActiGraph, Pensacola, FL). Participants will use the accelerometer for 7 days during a typical week, with at least three valid weekdays and one valid weekend day. To be considered a valid day, participants must use the accelerometer for at least 16 hours. Device initialization and data extraction will be performed using Actilife® software (v.6.9.1; Fort Walton Beach, FL), and data processing will be done using the open-source R package GGIR (version 2.6), with non-dominant wrist cut-points (light: 44.8 mg; moderate: 100.6 mg; vigorous: 428.8 mg)(40). Using an accelerometer, variables such as sleep duration and quality, and time spent in sedentary behavior, will also be recorded.

Handgrip strength will be assessed using a JAMAR dynamometer. A warm-up will precede the assessment to familiarize the participant with the instrument. The test is performed while seated in a chair, with the feet flat on the floor and the elbow at 90 degrees during isometric strength exertion (31). Three measurements will be collected from each upper limb, with a one-minute recovery interval between repetitions for the same limb. The final value will be the higher of the three measurements.

Cost-effectiveness The economic evaluation will be conducted from a societal perspective over the 6-month trial period. Results will be presented in incremental cost-effectiveness ratios, expressed by incremental costs per unit change in 2-hour glucose levels during the OGTT (18 mg/dL (1 mmol/L)), comparing each intervention group with the control group. Costs will be reported in 2026 euros and will be categorized into three groups: (1) intervention costs, including personnel time and salaries of healthcare professionals, and (2) direct costs, given by healthcare resource utilization, including medication, examinations and laboratory tests, consultations, hospitalizations, and emergency visits, and (3) indirect costs due to work absenteeism. Healthcare resource use will be measured using the iMedical Consumption Questionnaire to assess medical consumption costs (41), while productivity losses will be assessed using the Work Productivity and Activity Impairment (WPAI) questionnaire. The costs will be valued using official tariffs and published information from the Portuguese National Health Service. Indirect costs will be estimated using the human capital approach and valued using official wage tables. No discounting will be applied due to the short time horizon. Uncertainty will be assessed using scenario analysis and univariate sensitivity analysis.

The primary effectiveness outcome will be the mean change in 2-hour glucose levels during the OGTT. For the economic evaluation, the cost-effectiveness measure will be expressed as the cost (€) per 18 mg/dL (1

mmol/L) reduction in glucose. Costs will include personnel time and salaries of healthcare professionals, material for the training sessions, and the rent of infrastructure, and also, potential savings with the interventions, such as healthcare resource utilization, including medication, consultations, hospitalizations, emergency visits, and work absenteeism, including the iMedical Consumption Questionnaire to measure medical consumption costs(41).

Plans to promote participant retention and complete follow-up {25b}

As explored in part 15c, the monthly meetings will help keep participants engaged in the trial, even if they are allocated to the control group or exhibit lower adherence to the program. After the first 6 months, the program will remain open to everyone, and the monthly meetings will continue to prevent dropouts from the 6- to 12-month assessments. .

Data management {26}

Data entry, processing, and management will be conducted by two researchers under the supervision of the Principal Investigator (PI), according to the following procedures:

1. All measurements collected during the study will be compiled into a secure central database. To ensure confidentiality, a unique identification code (ID) will be generated for each participant.
2. Data collected via surveys will be exported and securely archived in a dedicated dataset.
3. A new, secure database will be established to store anonymized data from all project domains.
4. Data quality will be ensured through systematic controls and regular documentation checks to identify and correct potential data entry errors."

Confidentiality {33}

Participant confidentiality will be strictly maintained throughout the study. All electronic data will be pseudonymized, encrypted, and stored in a secure database; participants will be identified solely by a unique study ID number. The correspondence key linking the study ID to personal participant data (Master Linking Log) will be stored in a separate, restricted database accessible only to the Principal Investigator.

Both databases will be hosted on a secure server at the Faculty of Human Kinetics (FMH). The anonymized research data will be retained for 10 years for research purposes. However, the database containing personal identifiers will be destroyed 5 years after the study concludes. Physical records and biological samples will be

archived at the FMH Exercise and Health Laboratory, with all identifiers removed and replaced with study IDs to ensure confidentiality.

Statistical methods

Statistical methods for primary and secondary outcomes {27a}

Statistical analysis will be performed using STATA version 13.1 (StataCorp LLC, College Station, TX, USA and the Statistical Package for the Social Sciences (SPSS) 24.0 (IBM Corp., Armonk, New York). Significance will be set at $p \leq 0.05$. For the three groups, linear mixed models with random intercepts will be used to analyze changes in the intervention effect and between-group differences in OGTT 2h glucose at 6 and 12 months, as well as other secondary outcomes. Models will be adjusted for age, sex, and baseline differences. Effect sizes for between-group differences will be calculated using Cohen's *d* based on the estimated marginal means, with thresholds of 0.2, 0.5, and 0.8 defined as small, medium, and large effects, respectively. For the economic evaluation, the incremental cost-effectiveness ratios will be estimated by computing incremental costs per unit change in 2-hour glucose levels during the OGTT, comparing each intervention group with the control group. The uncertainty will be handled by defining different scenarios and performing univariate sensitivity analysis for key parameters.

Who will be included in each analysis {27b}

Other than the intention-to-treat analysis with a last observation carried forward (i.e., inclusion of all participants who were initially randomized) and the per-protocol analysis (i.e., inclusion of only participants who completed the study and had at least 70% adherence to the total number of trainings).

How missing data will be handled in the analysis {27c}

We will not use any other statistical methods to handle missing data.

Methods for additional analyses (e.g. subgroup analyses) {27d}

Not applicable. The sample size in this trial will not allow subgroup analysis

Interim analyses {28b}

The research team did not consider it necessary to conduct an interim analysis or to establish stopping guidelines.

Protocol and statistical analysis plan {5}

All details regarding data management, statistical methods, and planned analyses are described within the methods section of this manuscript. No separate complete statistical analysis plan document will be generated.

Oversight and monitoring

Composition of the coordinating centre and trial steering committee {3d}

At the beginning of the study, a steering committee will be established to supervise the trial. Led by the principal investigator (PI) and composed of a small group, the committee will ensure efficient oversight of trial operations. Weekly meetings with the research team will be held to review study progress and propose corrective actions for any deviations from the predefined trial plan.

Composition of the data monitoring committee, its role and reporting structure {28a}

A data monitoring committee will not be required for the “More Health, Less Diabetes” trial, as the intervention poses minimal risk of harm. The research team will continuously monitor participants’ safety and intervention progress, and any required protocol adjustments will be discussed.

Frequency and plans for auditing trial conduct {29}

The research team will hold weekly meetings to review participant and intervention progress, address emerging issues, and consider necessary protocol modifications. These meetings will also serve to monitor participant safety, outcome data, and adverse event records.

Protocol amendments {31}

Any necessary protocol updates will first be communicated to the sponsor and funder. Subsequently, the principal investigator will submit the revised version to the ethics committee. This process ensures transparency and accountability throughout the study. Finally, the protocol will be updated in the clinical trial registry to provide all stakeholders with accurate, up-to-date information about the trial.

Dissemination policy {8}

It is expected that at least four papers will be publish with data from this project in international peer-review journals with significant impact factor and within the first quartile: (1) research protocol; (2) results of our

primary objective on postprandial glucose between three different groups after 6-months of intervention and 12-months follow-up period (3) results of cost-effectiveness of the program with social return on investment between the three different groups; (4) Inter-individual response in glycemic control to standardized exercise performed in the online vs. in person groups. Additional studies may be conducted to explore secondary outcomes, using variables from BIA, DXA, questionnaires, CPET, and handgrip strength. Data from this project can also lead to a Ph.D. thesis, master's thesis, reports, and seminars.

Moreover, results from this study will be presented at national and international scientific conferences. Dissemination to the general public will be done through social media posts, and summary reports presented by FMH-UL, the Portuguese Directorate-General of Health, and its National Diabetes Program.

Discussion

This manuscript presents a detailed explanation of “More Health, Less Diabetes”, a trial that aims to assess the effectiveness and cost-effectiveness of in-person and online lifestyle 6-month intervention on 2h postprandial glycemia in an OGTT and at the 12-month follow-up period, in people with an increased risk of developing T2DM. At the same time, this project aims to promote a healthy lifestyle and health literacy among individuals at increased risk of developing T2DM, while offering a flexible exercise program that can be scaled nationally.

Type 2 diabetes and intermediate hyperglycemia are a critical public health problem with an increasing prevalence and incidence trend (1). In fact, 70% of people with intermediate hyperglycemia tend to develop T2DM mellitus in 10 years (3). This high risk of developing T2DM within 10 years is directly influenced by BMI and waist circumference, physical inactivity, unhealthy diet, and poor health literacy (4). Beyond that, since the onset of pre-diabetes, there is compelling evidence of structural and functional vascular changes that contribute to both macrovascular and microvascular complications (5,6).

There is a body of literature supporting the effectiveness of lifestyle interventions in preventing the development of T2DM in individuals with intermediate hyperglycemia (10, 42, 43), including the educational component of this program, which has already proven the effectiveness of the educational intervention in reducing T2DM risk factors (44). The Diabetes Prevention Program showed a 58 percent reduction in diabetes incidence with lifestyle intervention and a 31 percent reduction with pharmacological intervention, compared with placebo (9). Their 15-year follow-up study reported greater improvements with lifestyle intervention than with medication alone (9). The Finnish Diabetes Prevention Study confirmed this trend, concluding that

intensive lifestyle intervention led to long-term beneficial changes in diet, physical activity, and weight, thereby reducing the risk of diabetes (43). These long-lasting effects of lifestyle intervention can extend the time free of diabetes by 5 years (45). Beyond demonstrating effectiveness, there is also a need to assess the cost-effectiveness of these interventions, as in-person lifestyle programs have generally been shown to be more cost-effective than participation among individuals who do not participate (46). Nevertheless, comparability across studies is limited due to heterogeneity in intervention type, design, and delivery (11, 15, 16). Also, the main questions remain about the mode of delivery, as online programs appear to be more scalable, less expensive, and a plausible, cost-effective alternative to in-person interventions, with some cases showing even better adherence. (19, 24, 25). However, other authors reported that online interventions have shown that improvements in health-related outcomes and adherence may be compromised in the medium to long term (18-20).

Although exercise programs have demonstrated effectiveness and cost-effectiveness in individuals at risk of developing T2DM, evidence remains unclear regarding the type, design, and delivery of these interventions. The “More Health, Less Diabetes” project will serve as a proof-of-concept, evidence-based exercise program tailored to individuals at risk of T2DM. Ultimately, this project will provide high-quality evidence on the comparative effectiveness and cost-effectiveness of in-person and online lifestyle interventions, supporting future large-scale implementation strategies for T2DM prevention.

Trial status

The current protocol version is dated 20/10/2026. Recruitment began on the 1st of September 2025. On the 20th of October, the study began and is ongoing. Due to delays in finalizing the manuscript, we were unable to submit it before the start of the study.

Abbreviations

T2DM- type 2 diabetes mellitus

RCT- randomized controlled trial

IPIG- in-person intervention group

OIG- online intervention group

OGTT- oral glucose tolerance test

AMRAP- as many rounds as possible

EMOM- every minute on the minute

MHLD- more health, less diabetes

DXA-dual energy X-ray absorptiometry

BIA- Bioelectrical impedance analysis

CPET- cardiopulmonary exercise test

PPO- peak power output

HbA1c- glycated hemoglobin

IMCQ- IMTA medical consumption questionnaire

BMI-Body mass index

REE- rest energy expenditure

W- Watts

R- resistance

XC- reactance

Declarations

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Authors' contributions {3a}

AV, RF, JD, EP, ECO, MP, JA, MS, MJG, OS, SF, RP, LBS, AMS, Rm, JM, and SV were involved in the study's conception and design. TC, CM, and JSM contributed to the recruitment and screening of patients involved in the trial. AV, RF, JD, EP, ECO, MP, TC, CM, JSM, MJG, RP, JM, and SV were responsible for data acquisition, analysis, and interpretation. AV, RF, JPM, SV, and RM contributed to the discussion and reviewed/edited the manuscript. MNS, JA, SF, RP, CM, AMS, and OS reviewed/edited the manuscript. AV, LBS, AMS, RM, JM, and SV researched the data and critically revised it for its intellectual content. All authors approved the final version and agreed to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work were appropriately investigated and resolved. All

authors read and approved the final manuscript.

Sources of funding and other support {7a}

This study is funded by the Portuguese Directorate-General of Health, through the Portuguese National Diabetes Program. The three authors from PND, which is part of the Portuguese Directorate-General of Health, played a role in designing and implementing the program's educational component. The PNPAF authors contributed to the development of digital educational program tools. The funder has no role in the program's exercise component. This trial is also funded by the Fundação para a Ciência e Tecnologia via a Ph.D. fellowship (2025.05875.BD).

Availability of data and materials {6}

Anonymized trial data will be available for non-commercial research purposes only upon request to the PI.

Ethics approval and consent to participate {30}

This study protocol was approved by the Ethics Commission for Health of the Local Health Unit of Western Lisbon (approval code: 2025-15)

Consent for publication

Before data collection, each participant will receive a comprehensive oral and written explanation of the study. Participants will be encouraged to ask questions before providing signed informed consent. A copy of our model consent form is available upon request.

Competing interests {7b}

The authors declare the following potential conflict of interest: This research was funded by the Directorate-General of Health (DGS). Furthermore, representatives of the DGS are also co-authors of this manuscript.

Authors’ information (optional)

No additional author information to add.

References

1. Duncan BB, Magliano DJ, Boyko EJ. IDF diabetes atlas 11th edition 2025: global prevalence and projections for 2050. Nephrol Dial Transplant. 2025.
2. Diabetologia SPd. Diabetes: Factos e Números- O ano de 2022, 2023 e 2024- Relatório Anual do Observatório Nacional de Diabetes
2025.
3. PND. Programa Nacional para a Diabetes: Desafios e Estratégias. 2025.
4. Beulens J, Rutters F, Rydén L, Schnell O, Mellbin L, Hart HE, et al. Risk and management of pre-diabetes. Eur J Prev Cardiol. 2019;26(2_suppl):47-54.
5. Ligthart S, van Herpt TT, Leening MJ, Kavousi M, Hofman A, Stricker BH, et al. Lifetime risk of developing impaired glucose metabolism and eventual progression from prediabetes to type 2 diabetes: a prospective cohort study. Lancet Diabetes Endocrinol. 2016;4(1):44-51.
6. Wasserman DH, Wang TJ, Brown NJ. The Vasculature in Prediabetes. Circulation Research. 2018;122(8):1135-50.
7. Green DJ, Hopman MT, Padilla J, Laughlin MH, Thijssen DH. Vascular Adaptation to Exercise in Humans: Role of Hemodynamic Stimuli. Physiol Rev. 2017;97(2):495-528.
8. Barbosa A, João B, Pedro F, André S, Ding D, Romeu M. How much does it cost to implement a community-based walking football programme for patients with type 2 diabetes? BMJ Open Sport & Exercise Medicine. 2023;9(2):e001549.
9. Hamman RF, Wing RR, Edelstein SL, Lachin JM, Bray GA, Delahanty L, et al. Effect of Weight Loss With Lifestyle Intervention on Risk of Diabetes. Diabetes Care. 2006;29(9):2102-7.
10. DPPRG. Reduction in the Incidence of Type 2 Diabetes with Lifestyle Intervention or Metformin. New England Journal of Medicine. 2002;346(6):393-403.
11. DPPRG. Long-term effects of lifestyle intervention or metformin on diabetes development and microvascular complications over 15-year follow-up: the Diabetes Prevention Program Outcomes Study. Lancet Diabetes Endocrinol. 2015;3(11):866-75.
12. Magalhães JP, Santos DA, Correia IR, Hetherington-Rauth M, Ribeiro R, Raposo JF, et al. Impact of combined training with different exercise intensities on inflammatory and lipid markers in type 2 diabetes: a secondary analysis from a 1-year randomized controlled trial. Cardiovascular Diabetology. 2020;19(1):169.
13. Hetherington-Rauth M, Magalhães JP, Júdice PB, Melo X, Sardinha LB. Vascular improvements in individuals with type 2 diabetes following a 1 year randomised controlled exercise intervention, irrespective of changes in cardiorespiratory fitness. Diabetologia. 2020;63(4):722-32.
14. Magalhães JP, Júdice PB, Ribeiro R, Andrade R, Raposo J, Dores H, et al. Effectiveness of high-intensity interval training combined with resistance training versus continuous moderate-intensity training combined with resistance training in patients with type 2 diabetes: A one-year randomized controlled trial. Diabetes Obes Metab. 2019;21(3):550-9.
15. Magalhães JP, Melo X, Correia IR, Ribeiro RT, Raposo J, Dores H, et al. Effects of combined training with different intensities on vascular health in patients with type 2 diabetes: a 1-year randomized controlled trial. Cardiovascular Diabetology. 2019;18(1):34.

16. Mendes R, Sousa N, Reis VM, Themudo-Barata JL. Implementing Low-Cost, Community-Based Exercise Programs for Middle-Aged and Older Patients with Type 2 Diabetes: What Are the Benefits for Glycemic Control and Cardiovascular Risk? International Journal of Environmental Research and Public Health. 2017;14(9):1057.
17. Magalhães JP, Hetherington-Rauth M, Júdice PB, Correia IR, Rosa GB, Henriques-Neto D, et al. Interindividual Variability in Fat Mass Response to a 1-Year Randomized Controlled Trial With Different Exercise Intensities in Type 2 Diabetes: Implications on Glycemic Control and Vascular Function. Frontiers in Physiology. 2021;Volume 12 - 2021.
18. Correia IR, Hetherington-Rauth M, Magalhães JP, Júdice PB, Rosa GB, Henriques-Neto D, et al. Compensatory mechanisms from different exercise intensities in type 2 diabetes: a secondary analysis of a 1-year randomized controlled trial. Acta Diabetol. 2023;60(5):645-54.
19. Golovaty I, Wadhwa S, Fisher L, Lobach I, Crowe B, Levi R, et al. Reach, engagement and effectiveness of in-person and online lifestyle change programs to prevent diabetes. BMC Public Health. 2021;21(1):1314.
20. Wang Y, Chai X, Wang Y, Yin X, Huang X, Gong Q, et al. Effectiveness of Different Intervention Modes in Lifestyle Intervention for the Prevention of Type 2 Diabetes and the Reversion to Normoglycemia in Adults With Prediabetes: Systematic Review and Meta-Analysis of Randomized Controlled Trials. J Med Internet Res. 2025;27:e63975.
21. Dunstan DW, Vulikh E, Owen N, Jolley D, Shaw J, Zimmet P. Community Center–Based Resistance Training for the Maintenance of Glycemic Control in Adults With Type 2 Diabetes. Diabetes Care. 2006;29(12):2586-91.
22. Dunstan DW, Daly RM, Owen N, Jolley D, Vulikh E, Shaw J, et al. Home-Based Resistance Training Is Not Sufficient to Maintain Improved Glycemic Control Following Supervised Training in Older Individuals With Type 2 Diabetes. Diabetes Care. 2005;28(1):3-9.
23. Al Ozairi E, Alsaeed D, Al Roudhan D, Jalali M, Mashankar A, Taliping D, et al. The effect of home-based resistance exercise training in people with type 2 diabetes: A randomized controlled trial. Diabetes Metab Res Rev. 2023;39(7):e3677.
24. Smith DH, O'Keeffe-Rosetti M, Fitzpatrick SL, Mayhew M, Firemark AJ, Gruß I, et al. Costs and Cost-Effectiveness of Implementing a Digital Diabetes Prevention Program in a Large, Integrated Health System. Perm J. 2022;26(3):74-82.
25. Park S, Ballreich J, Ward T, Shi L. Cost-effectiveness analysis of a digital diabetes-prevention programme versus an in-person diabetes-prevention programme in people with prediabetes in the United States. Diabetes Obes Metab. 2024;26(10):4522-34.
26. Lindström J, Tuomilehto J. The Diabetes Risk Score: A Practical Tool to Predict Type 2 Diabetes Risk. Diabetes care. 2003;26:725-31.
27. Jeffreys I. Warm-up revisited: The ramp method of optimizing warm-ups. Professional Strength and Conditioning. (6) 12-18. Professional Strength and Conditioning. 2007:12-8.
28. Kanaley JA, Colberg SR, Corcoran MH, Malin SK, Rodriguez NR, Crespo CJ, et al. Exercise/Physical Activity in Individuals with Type 2 Diabetes: A Consensus Statement from the American College of Sports Medicine. Med Sci Sports Exerc. 2022;54(2):353-68.

29. Ntoumanis N, Ng JYY, Prestwich A, Quested E, Hancox JE, Thøgersen-Ntoumani C, et al. A meta-analysis of self-determination theory-informed intervention studies in the health domain: effects on motivation, health behavior, physical, and psychological health. Health Psychol Rev. 2021;15(2):214-44.
30. Francisco R, Jesus F, Nunes CL, Alvim M, Campa F, Sardinha LB, et al. Comparison of series and parallel reactance to identify changes in intracellular water in response to physical training in athletes during a sports season. Nutrition. 2024;123:112414.
31. Francisco R, Jesus F, Nunes CL, Santos P, Alvim M, Campa F, et al. H2OAthletes study protocol: effects of hydration changes on neuromuscular function in athletes. Br J Nutr. 2024;131(9):1579-90.
32. Nunes CL, Matias CN, Santos DA, Morgado JP, Monteiro CP, Sousa M, et al. Characterization and Comparison of Nutritional Intake between Preparatory and Competitive Phase of Highly Trained Athletes. Medicina (Kaunas, Lithuania). 2018;54(3).
33. Schofield WN. Predicting basal metabolic rate, new standards and review of previous work. Human nutrition Clinical nutrition. 1985;39 Suppl 1:5-41.
34. Goldberg GR, Black AE, Jebb SA, Cole TJ, Murgatroyd PR, Coward WA, et al. Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. European journal of clinical nutrition. 1991;45(12):569-81.
35. Westerterp KR. Physical activity and physical activity induced energy expenditure in humans: measurement, determinants, and effects. Frontiers in physiology. 2013;4:90.
36. Graffar M. Une méthode de classification sociale d'échantillons de population. Courrier. 1956;6(8):455-9

37. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc. 2003;35(8):1381-95.
38. Martínez-González MA, García-Arellano A, Toledo E, Salas-Salvadó J, Buil-Cosiales P, Corella D, et al. A 14-item Mediterranean diet assessment tool and obesity indexes among high-risk subjects: the PREDIMED trial. PLoS One. 2012;7(8):e43134.
39. Herdman M, Gudex C, Lloyd A, Janssen MF, Kind P, Parkin D, et al. Development and preliminary testing of the new five-level version of EQ-5D (EQ-5D-5L). Quality of Life Research. 2011;20(10):1727-36.
40. Bos; Taren Sanders; Chenxuan Zhao; Ian Meneghel Danilevicz; Victor Barreto Mesquita; Gaia Segantin; Medical Research Council UK; Accelting; French National Research Agency VTvHJHMSSMRPZFJHJCPLKMCMYP. GGIR: Raw Accelerometer Data Analysis. 2025.
41. Bouwmans C, Krol M, Severens H, Koopmanschap M, Brouwer W, Hakkaart-van Roijen L. The iMTA Productivity Cost Questionnaire: A Standardized Instrument for Measuring and Valuing Health-Related Productivity Losses. Value Health. 2015;18(6):753-8.
42. Gong Q, Gregg EW, Wang J, An Y, Zhang P, Yang W, et al. Long-term effects of a randomised trial of a 6-year lifestyle intervention in impaired glucose tolerance on diabetes-related microvascular complications: the China Da Qing Diabetes Prevention Outcome Study. Diabetologia. 2011;54(2):300-7.
43. Lindström J, Louheranta A, Mannelin M, Rastas M, Salminen V, Eriksson J, et al. The Finnish Diabetes Prevention Study (DPS): Lifestyle intervention and 3-year results on diet and physical activity. Diabetes Care. 2003;26(12):3230-6.

44. Gomes A, Pedro E, Dores J, do Vale S. “More Health, Less Diabetes: Type 2 Diabetes Diagnosis and Prevention Program” – Pilot Project. Endocrinology Insights. 2025.
45. Lindström J, Peltonen M, Eriksson JG, Ilanne-Parikka P, Aunola S, Keinänen-Kiukaanniemi S, et al. Improved lifestyle and decreased diabetes risk over 13 years: long-term follow-up of the randomised Finnish Diabetes Prevention Study (DPS). Diabetologia. 2013;56(2):284-93.
46. Kuo S, Ye W, Wang D, McEwen LN, Villatoro Santos C, Herman WH. Cost-effectiveness of the National Diabetes Prevention Program: A Real-world, 2-Year Prospective Study. Diabetes Care. 2025;48(7):1180-8.